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ASSESSING THE EFFECTS OF HOOK, BAIT AND LEADER TYPE AS POTENTIAL MITIGATION MEASURES TO REDUCE BYCATCH AND MORTALITY RATES OF SHORTFIN MAKO: A META-ANALYSIS WITH COMPARISONS FOR TARGET, BYCATCH AND VULNERABLE FAUNA INTERACTIONS

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SUMMARY

A meta-analysis of 24 publications was conducted to assess effects of hook, bait and leader type on retention rates of target, bycatch and vulnerable species of the pelagic longline fishery. Retention rate and at-haulback mortality rate analyses considered hook type, bait type, the combination of both variables and leader type. Turtles and swordfish had a lower retention rate with circle hooks. In contrast, retention rates of 3 sharks and 2 tuna species were greater with circle hooks. Bait type alone did not seem to significantly influence the retention rates of most of the species examined. Results were mixed when considering the combined effects of hook and bait type. Wire leader led to a decrease in retention rates of bony fishes and a mix for elasmobranchs. For at-haulback mortality, hook type was the most influential, while bait type only influenced blue shark at-haulback mortality. Leader type did not have a significant effect. The results presented here should be considered preliminary. Future work will consider information on at-haulback mortality rates for bony fishes and sea turtle and expanded information on fishery characteristics.

RÉSUMÉ

Une méta-analyse de 24 publications a été réalisée pour évaluer les effets des types d'hameçons, d'appâts et de bas de ligne sur les taux de rétention des espèces cibles, des prises accessoires et des espèces vulnérables de la pêcherie palangrière pélagique. Les analyses du taux de rétention et du taux de mortalité à la remontée de l'engin ont porté sur le type d'hameçon, le type d'appât, la combinaison des deux variables et le type de bas de ligne. Les tortues et les espadons avaient un taux de rétention plus faible avec les hameçons circulaires. En revanche, les taux de rétention de trois espèces de requin et de deux espèces de thon étaient plus élevés avec les hameçons circulaires. Le type d'appât à lui seul ne semble pas avoir d'influence significative sur les taux de rétention de la plupart des espèces examinées. Les résultats ont été mitigés en ce qui concerne les effets combinés du type d'hameçon et d'appât. Les bas de ligne métalliques ont entraîné une diminution des taux de rétention des poissons osseux et un mélange pour les élasmobranches. En ce qui concerne la mortalité à la remontée de l'engin, le type d'hameçon était le facteur le plus influent, tandis que le type d'appât influait uniquement sur la mortalité du requin peau bleue. Le type de bas de ligne n'a pas eu d'effet significatif. Les résultats présentés ici doivent être considérés comme préliminaires. Les travaux futurs examineront des informations sur les taux de mortalité à la remontée de l'engin des poissons osseux et des tortues de mer ainsi que des informations plus complètes sur les caractéristiques de la pêche.

RESUMEN

Se realizó un meta-análisis de 24 publicaciones para evaluar los efectos del tipo de anzuelo, del cebo y del bajo de línea sobre las tasas de retención de especies objetivo, especies capturadas de forma fortuita y vulnerables de la pesquería de palangre pelágico. Los análisis de la tasa de retención y de la tasa de mortalidad en la virada consideran el tipo de anzuelo, el tipo de cebo, la combinación de ambas variables y el tipo de bajo de línea. Las tortugas y el pez

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espada presentaron una menor tasa de retención con anzuelos circulares. Por el contrario, las tasas de retención de tres especies de tiburones y dos especies de atún fueron mayores con anzuelos circulares. El tipo de cebo por sí solo no pareció influir significativamente en las tasas de retención de la mayoría de las especies examinadas. Los resultados fueron mixtos cuando se consideraron los efectos combinados del tipo de anzuelo y cebo. El bajo de línea de acero da lugar a una disminución en las tasas de retención de los peces óseos y a una mezcla para los elasmobranquios. En cuanto a la mortalidad en la virada, el tipo de anzuelo fue el factor más influyente, mientras que el tipo de cebo sólo influyó en la mortalidad de la tintorera en la virada. El tipo de bajo de línea no tuvo un efecto significativo. Los resultados presentados aquí deben considerarse preliminares. El trabajo futuro considerará la información sobre las tasas de mortalidad de peces óseos y tortugas marinas en la virada y la ampliación de la información sobre las características de la pesquería.

KEYWORDS

J-hooks, circle hooks, squid, fish, target, bycatch

1. Introduction

Marine fisheries have a major anthropogenic influence on marine systems worldwide, affecting both marine populations and ecosystems, and warranting urgent and comprehensive management. Among the different key issues in marine fisheries, bycatch - the unintended capture of non-target organisms during fishing operations, is a major problem. Amongst these species are sea turtles, sharks and rays, seabirds and marine mammals. While some bycaught species are also commercial species, and therefore retained, others are discarded having no economical value. There is an evident need for measures that minimize catches of the bycatch species and/or measures that decrease mortality rates, that together with good handling practices, could decrease the at-haulback and post-release mortality.

Awareness of the impacts of incidental catches on species of concern is increasing, as well as the research on measures that minimize catch of non-target species. Gear modifications type of measures are seen as of easy implementation and low economical impact. The use of circle hooks instead of J-hooks is one of the measures seen as beneficial in reducing bycatch while maintaining the target species catch, however different results between studies and species have prevented a wider implementation of this measure. Besides hook type, bait species type has also been reported to have an effect on the catches of bycatch species. A species-specific meta-analysis of the changes in retention rate between hook, bait and leader type is presented in this study. At-haulback mortality between the different gear modifications is presented for elasmobranch species.

2. Methods

2.1. Data collection

Information from studies and experiments that examined hook type (circle, tuna or J-hook) effects, bait type (squid or fish) effects and leader type (nylon or steel) effects on retention and at-haulback mortality in pelagic longline fisheries was compiled. Published literature, technical reports and unpublished data relevant to our search were identified based on electronic database searches, using relevant keywords (e.g. “circle hook”, “bait type”, “leader type”, “pelagic longline”). Initial references were collected from a recent meta-analysis by Reinhardt *et al.* (2017). Furthers references in the available literature were also analysed if there was a match with the searching criteria. Following Reinhardt *et al.* (2017), the term “reference” is used to refer to a document; “experiment” to refer to a unique data set considered in our analysis. An experiment was considered unique if they differed with respect to attributes such as the year of study or season, location, gear, vessel size or fleet. Each unique experiment was assigned an identification number, and a unique reference could have more than one experiment. References used were collected by January 2019.

Data collected from each reference included date and location, set type, species name, hook type, size, offset and manufacturer, bait type, leader type, number of hooks, total catch, and at-haulback mortality. The set type was classified as "Deep-set" or "Shallow-set" depending on the longline depth during the fishing operation. If this information was not available, the target species and number of hooks between floats were used to differentiate between set type. Hook type was classified as "circle", "J" or "Tuna" hook. When available, information on hook size, offset and manufacturer were also recorded. Bait type was classified as "fish" or "squid" depending on the bait species used. Leader type was classified as "nylon" or "wire"; when available information on leader length was also recorded. Some values that were required, but not directly reported, were derived where possible. For example, the number of fish caught was often derived from retention rates and effort reported in the reference.

Data from the National Marine Fisheries Service (NMFS) Southeast Fisheries Science Center Pelagic Observer Program (POP), Epperly *et al.* (2012) and Foster *et al.* (2012) were obtained from Reinhardt *et al.* (2017). Data from Coelho *et al.* (2012), Amorim *et al.* (2015), Fernandez-Carvalho *et al.* (2015), Santos & Coelho (2016) and Santos *et al.* (2017) was used directly from the raw data provided by the authors.

2.2. Meta-analysis

For this initial analysis, only differences in catch rate for target (tuna and billfish species) and bycatch species (sharks and sea turtles) caught on different hook and bait type for surface pelagic longlines were analysed through a meta-analysis. Deep setting, tuna hooks, and the effects of leader type on catches were not investigated as well as at-haulback mortality. Our analysis follows the method used by Reinhardt *et al.* (2017) but is specific to the shallow pelagic longline fishery and expands the analysis to include bait type and the leader type. The difference between the calculated RR and a value of 1.0 represents the mean percent change associated with the experimental treatment, such that an RR < 1.0 indicates lower values for treatment compared with the control (e.g circle vs J-hooks).

The RR is equal to:

$$RR = \frac{ai/n1i}{ci/n2i}$$

where for the ith experiment, a_i is the number of animals retained on experimental hook (circle hook), $n1_i$ is the number of experimental hooks fished, c_i is the number of animals retained on control hooks (J-hooks), and $n2_i$ is the number of control hooks fished for the analysis of catch rate.

For the comparison between bait type, for the ith experiment, a_i is the number of animals retained on experimental bait (squid), $n1_i$ is the number of experimental hooks fished, c_i is the number of animals retained on control hooks (fish), and $n2_i$ is the number of control hooks fished for the analysis of catch rate.

For the combined effect of hook and bait, for the ith experiment, a_i is the number of animals retained on experimental hook and bait (J-hook with fish, or circle hook with squid, or circle hook with fish), $n1_i$ is the number of experimental hooks fished, c_i is the number of animals retained on control hooks (J hook with squid), and $n2_i$ is the number of control hooks fished for the analysis of catch rate.

The same methods apply to at-haulback mortality, where the a_i and c_i is be the number of animals dead at-haulback for the experiment and control, respectively, and $n1_i$ and $n2_i$ is the number of animals retained for the experiment and control, respectively.

Retention and at-haulback mortality rates were estimated using the "metafor" package (Viechtbauer, 2010) in R 3.5.1 (R Core Team, 2018) for each species. The RR value is log-transformed to normalize the distribution of effect sizes around zero and to meet the assumption of normality for the analysis. A summary effect size was computed for all taxa that had at least two experiment IDs. For this preliminary analysis, experiments with low sample size and large confidence intervals on the RR were excluded. A two-sided Wald-type Z test was used to test for differences between effects mean and zero. Effect sizes were estimated using a random effects model. The random effects model computes a global mean effect size based on a weighted mean of the studies' effect sizes. Weights were computed as the inverse of the sample variance and the between-study variance (τ2). Sample variance, v_i, for ln(RR) of the ith experiment was calculated as:

$$Vi = \frac{1}{ai} - \frac{1}{n1i} + \frac{1}{ci} - \frac{1}{n2i}$$

Heterogeneity factor (I^2) was calculated as a measure of total variation across experiments due to observed variability that is real. Values of I^2 vary from 0% to 100%, with higher values indicating greater heterogeneity between experiments.

3. Results

For data compilation, in total 35 unique references were identified, totalling 52 experiments. For this preliminary analysis, considering only shallow sets, 24 references were available, totalling 28 experiments. Retention rate analyses between hook type were performed for 23 species (8 bony fishes, 3 sea turtles, 12 elasmobranchs; **Table 1**), between bait type for 18 species (7 bony fishes, 3 turtles, 8 elasmobranchs; **Table 2**), between combinations of hook and bait type for 17 species (6 bony fishes, 3 turtles, 8 elasmobranchs; **Tables 3-5**), and between leader type for 13 species (6 bony fishes and 7 elasmobranchs, **Table 6**). At-haulback mortality was analysed for 11 elasmobranch species considering hook type (**Table 7**), 8 elasmobranch species considering bait type (**Table 8**), 7 species considering combinations of bait and hook type (**Tables 9-11**), and 4 species considering leader type (**Table 12**).

3.1. Retention rates

3.1.1. Hook type

Of the 23 analysed species, 12 species had lower retention rates on circle hooks when comparing to J-hooks (**Table 1, Figure 1**). Tuna species (albacore, bigeye tuna, bluefin tuna and yellowfin tuna) had higher retention rates on circle hooks, however significant differences were found only for albacore and bluefin tuna ($p<0.05$). On the other hand, all billfish species had lower retention with circle hooks, particularly swordfish and blue marlin, for which the difference was statistically significant. For the analysed turtle species, all had significantly lower retention rates when using circle hooks. For elasmobranch species, there was mixed effects, with 7 species having higher retention rates with circle hooks. For porbeagle, shortfin mako, tiger shark and crocodile shark this difference was significant, while the pelagic stingray was the only elasmobranch species to have a significantly lower catch rate with circle hooks comparing to J-hooks.

Overall, increases in catch rate with circle hooks (vs. J-hooks) ranged from 20% greater in the shortfin mako to 45% greater in the porbeagle. For target species, catch rate ranged from 30% greater in bluefin tuna to 41% greater in albacore when circle hooks were used. Among elasmobranchs, increases in catch rate using circle hooks were approximately 40% higher for the porbeagle, crocodile shark, tiger shark. Catch rate with circle hooks (vs. J-hooks) ranged from 17% lower in swordfish to 76% lower in the pelagic stingray. For blue marlin, catch rate was 30% lower when using circle hooks. Retention rates for all turtle species were lower (40-61%) when circle hooks were used rather than J-hooks.

3.1.2 Bait type

Of the 18 analysed species, 9 species had lower retention rates on fish baited hooks in comparison with squid baited hooks (**Table 2, Figure 2**). For the billfishes, it is noted that blue marlin had a RR higher than 1, meaning that the catch rate is higher with fish baited hooks, while for swordfish the bait type had no effect on the catch rate. For the tunas changing bait to fish decreased the catches, however differences were only statistically significant for albacore. Among sea turtles, the loggerhead sea turtle and the leatherback sea turtle had significantly lower retention rates when baiting hooks with fish. The olive ridley sea turtle had a slightly higher catch rate, but differences observed were not statistically significant. For elasmobranchs, 6 of the 8 species analysed had a higher catch rate with fish baited hooks, however differences were not statistically significant.

Catch rate with fish baited hooks (vs. squid baited hooks) ranged from 49% lower in the leatherback sea turtle to 81% lower in the albacore.

3.1.3 Hook and Bait type

Considering the effects of changing bait type and maintaining the baseline hook (using J-hooks baited with fish vs. J-hooks baited with squid, **Table 3** and **Figure 3**) would significantly decrease the catches of the pelagic stingray, all sea turtles, albacore, bigeye tuna, yellowfin tuna and Atlantic sailfish. Retention rates of bigeye thresher shark, silky shark and shortfin mako increased significantly when J-hooks baited with fish were used. Catch rate with J-hooks baited with fish (vs. J-hooks baited with squid) ranged from 88% lower in the albacore to 65% greater in the silky shark.

Considering the effects of changing hook type but maintaining the bait type fixed (ie., using circle hooks baited with squid vs. J-hooks baited with squid, **Table 4 and Figure 4**) would significantly decrease the catches of the pelagic stingray and all turtles. The billfish and the smooth hammerhead shark retention rates were also lower, but the difference was not statistically significant. Retention rates when using circle hooks baited with squid instead of J-hooks baited with squid were higher for the other sharks and tuna species, however differences were only statistically significant for the albacore and bigeye tuna. Catch rate with circle hooks baited with squid (vs. J-hooks baited with squid) ranged from 83% lower in the pelagic stingray to 50% greater in the albacore.

When comparing changes in both variables at the same time, i.e., comparing J-hooks baited with squid vs. circle hooks baited with fish (**Table 5** and **Figure 5**), retention rates of turtles were significantly lower with circle hooks baited with fish. The retention rates of target species were also significantly lower for swordfish, albacore and yellowfin tuna, as well as for some bycatch species such as Atlantic sailfish and white marlin (marginally significant for this later species). For elasmobranchs, lower retention rates were observed for oceanic whitetip, crocodile shark and pelagic stingray, with differences statistically significant for the pelagic stingray. Higher retention rates were observed for all other shark species, but differences were only statistically significant for shortfin mako. Retention rates with circle hooks baited with fish (vs. J-hooks baited with squid) ranged from 87% lower in the loggerhead sea turtle to 91% greater in the shortfin mako.

3.1.4 Leader type

Of the 13 analysed species, 5 species had higher retention rates on wire leaders when comparing to nylon leaders (**Table 6, Figure 6**). All billfishes and tuna species had lower retention rates on wire leader, except for sailfish which showed a non-significant increase, however significant differences were found only for albacore, yellowfin tuna and blue marlin ($p<0.05$). On the other hand, for elasmobranch species, there were mixed effects, with 3 species (blue shark, silky shark and shortfin mako) having higher retention rates with wire leaders, although this was only significant for blue shark. For bigeye thresher, pelagic stingray and crocodile shark, there was a decrease in retention rates when using wire leader, this difference was only significant for crocodile shark. For oceanic whitetip there was no difference in retention rate.

3.2. At-haulback mortality rates

3.2.1. Hook type

Of the 11 analysed species, 5 species had significantly lower at-haulback mortality rates on circle hooks when comparing to J-hooks (**Table 7, Figure 7**), while one species (porbeagle) showed a decrease in at-haulback mortality rate but it was not significant. Bigeye thresher, longfin mako, crocodile shark, smooth hammerhead shark and tiger shark had higher at-haulback mortality rate when using circle hooks, however this decrease was only significant for the bigeye thresher.

3.2.2. Bait type

Of the 8 analysed species, 4 species had significantly lower at-haulback mortality rates on fish baited hooks when comparing to squid baited hooks (**Table 8, Figure 8**), while the other 4 species showed a decrease in at-haulback mortality rate. Only for blue shark there was a significant increase in at-haulback mortality.

3.2.3. Hook and bait type

Considering the effects of changing bait type and maintaining the baseline hook (using J-hooks baited with fish vs. J-hooks baited with squid, **Table 9** and **Figure 9**) would significantly increase the at-haulback mortality rate of blue shark. There is a non-significant change in at-haulback mortality rate for oceanic whitetip and shortfin mako, while there is a decrease for crocodile shark and smooth hammerhead shark.

Considering the effects of changing hook type but maintaining the bait type fixed (ie., using circle hooks baited with squid vs. J-hooks baited with squid, **Table 10** and **Figure 10**) would significantly decrease the at-haulback mortality rate of blue shark.

When comparing changes in both variables at the same time, i.e., comparing J-hooks baited with squid vs. circle hooks baited with fish (**Table 11** and **Figure 11**), at-haulback mortality rates would increase for 5 of the 7 species analysed, but this change is only significant for blue shark.

3.2.4. Leader type

Of the 4 analysed species, blue shark, bigeye thresher and silky shark had lower at-haulback mortality rates on wire leaders when comparing to nylon leaders (**Table 12, Figure 12**), on the contrary oceanic whitetip had higher at-haulback mortality rates on wire leaders, however none of these differences was significant.

4. Discussion

4.1. Retention rates

The main results of our study are that sea turtles interactions seem to be reduced when J-hooks are changed to circle hooks, with even lower retention rates with fish baited hooks. For swordfish, the main target species of shallow pelagic longlines, there were also reductions in retention rates when using circle hooks instead of J-types. For other billfishes that are captured mostly as bycatch, there were also reductions, especially for the blue marlin. In contrast, retention rates of the bluefin tuna and albacore were greater with circle hooks. With regards to elasmobranchs, the retention rates for species such as porbeagle, shortfin mako, tiger shark and crocodile shark were higher when using circle hooks, while the pelagic stingray had lower retention rates with circle hooks.

Bait type alone did not seem to have a major influence on the retention rates of elasmobranchs and the majority of the bony fishes, both target and bycatch. For the loggerhead sea turtle and the leatherback sea turtle, interactions were lower when the bait used was fish. Albacore catches were higher when fish was used as bait.

For elasmobranchs in general, when both effects were considered simultaneously, it was noted that retention rates tended to increase both when squid was changed to fish and when J-hooks were changed to circle hooks. However, the significance was dependent on the species, and those effects were mostly noticeable for species like the shortfin mako. The main exception within the elasmobranch was the pelagic stingray, where significantly lower retention rates were obtained both when using circle hooks and fish bait.

For sea turtles, retention rates were lower whenever circle hooks were used. Additionally, when using J-hooks, sea turtle interactions decreased also when the bait used was fish instead of squid. Finally, for the main bony fishes, higher retention rates tended to be obtained when squid was used, including both tunas and billfishes. With regards to the hook types the effects were contrary, i.e., when using circle hooks there was a tendency for higher retention rates of tunas and lower retention rates of billfishes, including for swordfish.

Using wire leaders, leads to a decrease in retention of all analysed bony fishes, except for sailfish. For sharks there is a mixed effect, but only significant for blue shark. It was not possible to compare the retention rate of sea turtles by leader type as not enough information was available.

4.2. At-haulback mortality rates

At this point, at-haulback mortality rates were only analysed for elasmobranchs. Changing from J-hooks to circle hooks significantly decreased at-haulback mortality rates of 5 of the 11 analysed species, while a significant increase in at-haulback mortality was only observed for bigeye thresher.

Bait type, and the combinations of bait type and hook type, in general, had no significant effect on at-haulback mortality rates, except for blue shark, where at-haulback mortality rates were higher using fish baited hooks vs squid baited hooks and fish baited J-hooks or fish baited J-hooks vs squid baited J-hooks. When comparing squid baited circle hook with squid baited J hook there was a decrease in at-haulback mortality.

Few studies are available comparing at-haulback mortality by leader type, especially for the rarer elasmobranch species, therefore it was only possible to conduct this analysis for 4 species, and none of these has a significant change in at-haulback mortality rate when changing leader type.

4.3. Shortfin mako considerations

None of the measures analysed in this study would reduce retention rate for shortfin mako. Using circle hooks instead of J-hooks would lead to a 20% increase in shortfin mako retention. Using fish baited hooks also leads to an increase in shortfin mako retention although this is not significant ($p=0.07$). Modifications to the traditional gear (J-hook baited with squid) would lead to 62% and 91% increases in retention rate of shortfin mako when using fish baited J-hooks and fish baited circle hooks, respectively. Using wire leaders instead of nylon leaders, leads to an increase in retention rate, although this is not significant.

For at-haulback mortality rates, the only measure that would decrease at-haulback mortality is using circle hooks instead of J-hooks. This modification would lead to a 10% decrease in at-haulback mortality rate. It was not possible to analyse at-haulback mortality rate by leader type, as only two studies with low sample sizes are available, however for the analysed species, leader type did not influence at-haulback mortality.

Another caveat is the difficulty in estimating what would be the effects of changing hook types on the post-release mortality. On one hand J-hooks tend to deep hook the specimens more than circle hooks, which could imply that the post-release mortality due to internal injuries would be larger. On the other hand, sharks that are able to bite-off and escape from J-hooks, spend much less time hooked (lower retention times) which in this case would likely imply a higher survival rate. As such, it is very difficult to estimate what could be the implications on the post-release mortality of using one hooks type versus the other, especially on specimens that can bite-off the line and escape when using J-hooks.

It is important to note that the results presented here are preliminary. For some species, only few studies were available, therefore the data used does not allow for strong conclusions, especially on the combinations of the effects of hook and bait type and leader type. More experimental studies are needed, especially for the more rare species with low sample sizes. Further work will include information on at-haulback mortality rates for the remaining species, and, if possible, expand on fishery characteristics considered (e.g. include tuna hooks and deep setting data).

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Table 1. Summary of the results of the meta-analysis on retention rates showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a higher retention was calculated on circle hooks vs J-hooks. If the p-value <0.05 the RR is significantly different from 1 (in bold). I^2 describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	#exp	RR	CI	I^2	p-value	References
Elasmobranchs						
BSH – Blue shark	14	1.09	0.94-1.26	99.13%	0.26	Bolten and Bjorndal, 2005; Mejuto *et al.*, 2008; Sales *et al.*, 2010; Afonso *et al.*, 2011; NMFS, 2011; Pacheco *et al.*, 2011; Domingo *et al.*, 2012; Foster *et al.*, 2012; Afonso *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015; Coelho *et al.*, 2012
BTH – Bigeye thresher	4	0.84	0.69-1.04	76.85%	0.11	NMFS, 2011; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
FAL – Silky shark	6	0.94	0.63-1.40	88.83%	0.75	Afonso *et al.*, 2011; NMFS, 2011; Andraka *et al.*, 2013; Coelho *et al.*, 2012; Afonso *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015
LMA – Longfin mako	3	0.67	0.30-1.52	85.10%	0.34	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
OCS – Oceanic whitetip	5	1.05	0.80-1.39	18.63%	0.72	Pacheco *et al.*, 2011; Coelho *et al.*, 2012; Afonso *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
POR – Porbeagle	5	1.45	1.24-1.69	39.44%	**<0.0001**	NMFS, 2011; Domingo *et al.*, 2012; Foster *et al.*, 2012; Amorim *et al.*, 2015
PSK – Crocodile shark	5	1.43	1.06-1.93	80.93%	**0.02**	Pacheco *et al.*, 2011; Coelho *et al.*, 2012; Afonso *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
SMA – Shortfin mako	10	1.20	1.01-1.20	88.04%	**0.04**	Mejuto *et al.*, 2008; Sales *et al.*, 2010; Afonso *et al.*, 2011; NMFS, 2011; Domingo *et al.*, 2012; Foster *et al.*, 2012; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
SPL – Scalloped hammerhead	5	0.95	0.46-1.97	53.51%	0.90	Afonso *et al.*, 2011; NMFS, 2011; Pacheco *et al.*, 2011; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015
SPZ – Smooth hammerhead	3	1.05	0.69-1.61	69.23%	0.82	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
TIG – Tiger shark	4	1.42	1.30-1.54	0%	**<0.0001**	NMFS, 2011; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Afonso *et al.*, 2012
PLS – Pelagic stingray	9	0.24	0.15-0.38	77.51%	**<0.0001**	Pacheco *et al.*, 2011; Cambie *et al.*, 2012; Domingo *et al.*, 2012; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Afonso *et al.*, 2012; Amorim *et al.*, 2015; Piovano *et al.*, 2009
Turtles						
TTL – Loggerhead sea turtle	18	0.46	0.33-0.65	91.31%	**<0.0001**	Bolten and Bjorndal, 2005; Boggs and Swimmer, 2007; Gilman *et al.*, 2007; Mejuto *et al.*, 2008; Sales *et al.*, 2010; NMFS, 2011; Cambie *et al.*, 2012; Domingo *et al.*, 2012; Epperly *et al.*, 2012; Foster *et al.*, 2012; Piovano *et al.*, 2012; Santos *et al.*, 2012; Piovano *et al.*, 2009; Coelho *et al.*, 2015; Santos *et al.*, 2013
DKK – Leatherback sea turtle	9	0.39	0.28-0.56	82.62%	**<0.0001**	Gilman *et al.*, 2007; Mejuto *et al.*, 2008; Sales *et al.*, 2010; NMFS, 2011; Pacheco *et al.*, 2011; Foster *et al.*, 2012; Santos *et al.*, 2012; Coelho *et al.*, 2015; Santos *et al.*, 2013
LKV – Olive ridley sea turtle	6	0.60	0.43-0.83	56.73%	**<0.01**	Mejuto *et al.*, 2008; Andraka *et al.*, 2013; Santos *et al.*, 2012; Coelho *et al.*, 2015
Target species						
SWO – Swordfish	18	0.83	0.75-0.91	98.38%	**0.0001**	Bolten and Bjorndal, 2005; Boggs and Swimmer, 2007; Gilman *et al.*, 2007; Mejuto *et al.*, 2008; Sales *et al.*, 2010; NMFS, 2011; Pacheco *et al.*, 2011; Domingo *et al.*, 2012; Foster *et al.*, 2012; Piovano *et al.*, 2012; Coelho *et al.*, 2012; Afonso *et al.*, 2012; Piovano *et al.*, 2009; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015

ALB – Albacore	10	1.41	1.02-1.94	95.63%	**0.04**	Sales *et al.*, 2010; NMFS, 2011; Pacheco *et al.*, 2011; Domingo *et al.*, 2012; Foster *et al.*, 2012; Coelho *et al.*, 2012; Afonso *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
BET – Bigeye tuna	5	1.04	0.64-1.67	98.76%	0.89	Sales *et al.*, 2010; NMFS, 2011; Pacheco *et al.*, 2011; Domingo *et al.*, 2012; Foster *et al.*, 2012
BFT – Bluefin tuna	3	1.30	1.04-1.62	56.44%	**0.02**	NMFS, 2011; Cambie *et al.*, 2012; Foster *et al.*, 2012
YFT – Yellowfin tuna	8	1.07	0.89-1.29	85.82%	0.47	Sales *et al.*, 2010; NMFS, 2011; Pacheco *et al.*, 2011; Domingo *et al.*, 2012; Coelho *et al.*, 2012; Afonso *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
BUM – Atlantic blue marlin	6	0.70	0.61-0.80	36.23%	<**0.0001**	NMFS, 2011; Pacheco *et al.*, 2011; Coelho *et al.*, 2012; Afonso *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
SAI – Atlantic sailfish	3	0.60	0.28-1.28	59.38%	0.19	Coelho *et al.*, 2012; Afonso *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015
WHM – White marlin	4	0.75	0.39-1.44	96.77%	0.38	NMFS, 2011; Pacheco *et al.*, 2011; Coelho *et al.*, 2012; Amorim *et al.*, 2015

Table 2. Summary of the results of the meta-analysis on retention rates showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a higher retention was calculated on fish baited hooks vs squid baited hooks. If the p-value <0.05 the RR is significantly different from 1 (in bold). I² describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	**#exp**	**RR**	**CI**	**I²**	**p-value**	**References**
Elasmobranchs						
BSH – Blue shark	6	1.07	0.77-1.47	99.69%	0.70	Foster *et al.*, 2012; Coelho *et al.*, 2012; Yokota *et al.*, 2009; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015; Santos and Coelho, 2016
BTH – Bigeye thresher	4	1.10	0.86-1.41	61.11%	0.45	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015; Santos and Coelho, 2016
FAL – Silky shark	4	1.46	0.82-2.61	60.64%	0.20	Coelho *et al.*, 2012; Yokota *et al.*, 2009; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015; Santos and Coelho, 2016
OCS – Oceanic whitetip	4	0.82	0.60-1.13	45.10%	0.23	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015; Santos and Coelho, 2016
PSK – Crocodile shark	4	0.72	0.21-2.49	99.12%	0.60	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015; Santos and Coelho, 2016
SMA – Shortfin mako	6	1.45	0.96-2.18	94.17%	0.07	Foster *et al.*, 2012; Coelho *et al.*, 2012; Yokota *et al.*, 2009; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015; Santos and Coelho, 2016
SPZ – Smooth hammerhead	3	1.11	0.50-2.50	91.40%	0.80	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Santos and Coelho, 2016
PLS – Pelagic stingray	5	1.07	0.64-1.81	81.98%	0.79	Coelho *et al.*, 2012; Yokota *et al.*, 2009; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015; Santos and Coelho, 2016
Turtles						
TTL – Loggerhead sea turtle	8	0.22	0.13-0.36	77.42%	**<0.001**	Boggs and Swimmer 2007; Gilman *et al.*, 2007; Foster *et al.*, 2012; Santos *et al.*, 2012; Yokota *et al.*, 2009; Coelho *et al.*, 2015; Santos *et al.*, 2013; Santos and Coelho, 2016
DKK – Leatherback sea turtle	6	0.51	0.27-0.94	89.27%	**<0.001**	Gilman *et al.*, 2007; Foster *et al.*, 2012; Santos *et al.*, 2012; Coelho *et al.*, 2015; Santos *et al.*, 2013; Santos and Coelho, 2016
LKV – Olive ridley sea turtle	3	1.01	0.22-4.59	94.61%	0.99	Santos *et al.*, 2012; Coelho *et al.*, 2015; Santos and Coelho, 2016
Target species						
SWO – Swordfish	7	1.00	0.83-1.21	99.02%	0.97	Gilman *et al.*, 2007; Foster *et al.*,2012; Coelho *et al.*, 2012; Yokota *et al.*, 2009; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015; Santos and Coelho, 2016
ALB – Albacore	5	0.19	0.09-0.42	87.70%	**<0.0001**	Foster *et al.*,2012; Coelho *et al.*, 2012; Yokota *et al.*, 2009; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
BET – Bigeye tuna	6	0.61	0.20-1.87	99.22%	0.38	Foster *et al.*,2012; Coelho *et al.*, 2012; Yokota *et al.*, 2009; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015; Santos and Coelho, 2016
YFT – Yellowfin tuna	4	0.60	0.25-1.45	97.11%	0.26	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015; Santos and Coelho, 2016
BUM – Atlantic blue marlin	4	1.48	0.86-2.53	90.31%	0.15	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015; Santos and Coelho, 2016
SAI – Atlantic sailfish	3	0.67	0.17-2.71	92.41%	0.58	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Santos and Coelho, 2016
WHM – White marlin	3	0.52	0.13-2.12	97.08%	0.36	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Santos and Coelho, 2016

Table 3. Summary of the results of the meta-analysis on retention rates showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a higher retention was calculated on fish baited J-hooks vs squid baited J-hooks. If the p-value <0.05 the RR is significantly different from 1 (in bold)**.** I^2 describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	**#exp**	**RR**	**CI**	**I^2**	**p-value**	**References**
Elasmobranchs						
BSH – Blue shark	4	0.84	0.69-1.04	76.85%	0.11	Foster *et al.*, 2012; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
BTH – Bigeye thresher	3	1.44	1.10-1.88	25.08%	**0.01**	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
FAL – Silky shark	2	1.65	1.12-2.43	0%	**0.01**	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015
LMA – Longfin mako	2	1.49	0.33-6.73	79.47%	0.60	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015
OCS – Oceanic whitetip	3	0.99	0.67-1.45	0%	0.96	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
PSK – Crocodile shark	3	0.35	0.06-2.13	97.97%	0.25	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
SMA – Shortfin mako	4	1.62	1.02-2.57	87.37%	**0.04**	Foster *et al.*, 2012; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
SPZ – Smooth hammerhead	2	1.29	0.73-2.27	66.55%	0.38	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015
PLS – Pelagic stingray	3	0.62	0.39-0.96	51.28%	**0.03**	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
Turtles						
TTL – Loggerhead sea turtle	4	0.26	0.19-0.36	0%	**<0.0001**	Foster *et al.* 2012; Santos *et al.*, 2012; Santos *et al.*, 2013; Coelho *et al.*, 2015
DKK – Leatherback sea turtle	4	0.41	0.29-0.58	2.19%	**<0.0001**	Foster *et al.* 2012; Santos *et al.*, 2012; Santos *et al.*, 2013; Coelho *et al.*, 2015
LKV – Olive ridley sea turtle	2	0.50	0.33-0.77	0%	**<0.01**	Santos *et al.*, 2012; Coelho *et al.*, 2015
Target species						
SWO – Swordfish	4	0.87	0.67-1.12	97.54%	0.28	Foster *et al.*, 2012; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*,2015
ALB – Albacore	3	0.12	0.02-0.85	83.59%	**<0.001**	Foster *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*,2015
BET – Bigeye tuna	4	0.27	0.09-0.80	95.96%	**0.02**	Foster *et al.*, 2012; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*,2015
YFT – Yellowfin tuna	3	0.59	0.46-0.77	16.34%	**<0.001**	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*,2015
BUM – Atlantic blue marlin	3	1.25	0.98-1.58	0%	0.07	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*,2015
SAI – Atlantic sailfish	2	0.23	0.11-0.46	0%	**<0.0001**	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015
WHM – White marlin	2	0.25	0.02-3.56	73.59%	0.30	Coelho *et al.*, 2012; Amorim *et al.*,2015

Table 4. Summary of the results of the meta-analysis on retention rates showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a higher retention was calculated on squid baited circle hooks vs squid baited J-hooks. If the p-value <0.05 the RR is significantly different from 1 (in bold)**.** I^2 describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	**#exp**	**RR**	**CI**	**I^2**	**p-value**	**References**
Elasmobranchs						
BSH – Blue shark	4	1.09	0.94-1.27	96.54%	0.25	Foster *et al.*, 2012; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
BTH – Bigeye thresher	3	1.16	0.97-1.38	0%	0.11	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
FAL – Silky shark	2	1.03	0.72-1.49	0%	0.85	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015
LMA – Longfin mako	2	1.16	0.47-2.86	51.95%	0.75	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015
OCS – Oceanic whitetip	3	1.11	0.72-1.70	30.26%	0.64	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
PSK – Crocodile shark	3	1.26	0.89-1.79	83.84%	0.19	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
SMA – Shortfin mako	4	1.12	0.83-1.51	74.43%	0.47	Foster *et al.*, 2012; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
SPZ – Smooth hammerhead	2	0.96	0.71-1.28	0%	0.76	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015
PLS – Pelagic stingray	3	0.17	0.10-0.29	37.19%	**<0.0001**	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
Turtles						
TTL – Loggerhead sea turtle	4	0.50	0.35-0.70	36.25%	**<0.0001**	Foster *et al.* 2012; Santos *et al.*, 2012; Santos *et al.*, 2013; Coelho *et al.*, 2015
DKK – Leatherback sea turtle	4	0.38	0.29-0.48	0%	**<0.0001**	Foster *et al.* 2012; Santos *et al.*, 2012; Santos *et al.*, 2013; Coelho *et al.*, 2015
LKV – Olive ridley sea turtle	2	0.43	0.30-0.61	0%	**<0.0001**	Santos *et al.*, 2012; Coelho *et al.*, 2015
Target species						
SWO – Swordfish	4	0.40	0.13-1.26	99.87%	0.12	Foster *et al.*, 2012; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*,2015
ALB – Albacore	3	1.50	1.19-1.89	39.87%	**<0.001**	Foster *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*,2015
BET – Bigeye tuna	4	1.32	1.20-1.45	15.26%	**<0.0001**	Foster *et al.*, 2012; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*,2015
YFT – Yellowfin tuna	3	1.29	0.87-1.89	78.68%	0.20	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*,2015
BUM – Atlantic blue marlin	3	0.87	0.70-1.09	0%	0.23	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*,2015
SAI – Atlantic sailfish	2	0.25	0.04-1.50	67.70%	0.13	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015
WHM – White marlin	2	0.97	0.59-1.61	58.60%	0.12	Coelho *et al.*, 2012; Amorim *et al.*,2015

Table 5. Summary of the results of the meta-analysis on retention rates showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a higher retention was calculated on fish baited circle hooks vs squid baited J-hooks. If the p-value <0.05 the RR is significantly different from 1 (in bold)**.** I^2 describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	**#exp**	**RR**	**CI**	**I^2**	**p-value**	**References**
Elasmobranchs						
BSH – Blue shark	4	1.33	0.78-2.28	99.75%	0.30	Foster *et al.*, 2012; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
BTH – Bigeye thresher	3	1.13	0.77-1.67	63.30%	0.53	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
FAL – Silky shark	2	1.19	0.26-5.45	86.94%	0.83	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015
LMA – Longfin mako	2	1.13	0.35-3.69	72.70%	0.84	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015
OCS – Oceanic whitetip	3	0.94	0.67-1.31	0%	0.70	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
PSK – Crocodile shark	3	0.71	0.16-3.24	98.85%	0.66	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
SMA – Shortfin mako	4	1.91	1.16-3.16	92.36%	**0.01**	Foster *et al.*, 2012; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
SPZ – Smooth hammerhead	2	1.18	0.31-4.48	93.63%	0.80	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015
PLS – Pelagic stingray	3	0.19	0.05-0.67	90.11%	**0.01**	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*, 2015
Turtles						
TTL – Loggerhead sea turtle	4	0.13	0.09-0.17	0%	**<0.0001**	Foster *et al.* 2012; Santos *et al.*, 2012; Santos *et al.*, 2013; Coelho *et al.*, 2015
DKK – Leatherback sea turtle	4	0.19	0.11-0.32	46.19%	**<0.0001**	Foster *et al.* 2012; Santos *et al.*, 2012; Santos *et al.*, 2013; Coelho *et al.*, 2015
LKV – Olive ridley sea turtle	2	0.16	0.10-0.27	0%	**<0.0001**	Santos *et al.*, 2012; Coelho *et al.*, 2015
Target species						
SWO – Swordfish	4	0.64	0.51-0.81	97.70%	**<0.001**	Foster *et al.*, 2012; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*,2015
ALB – Albacore	4	0.29	0.10-0.79	89.90%	**0.02**	Foster *et al.*, 2012; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*,2015
BET – Bigeye tuna	4	0.45	0.17-1.23	98.25%	0.12	Foster *et al.*, 2012; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*,2015
YFT – Yellowfin tuna	3	0.43	0.35-0.53	0%	**<0.0001**	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*,2015
BUM – Atlantic blue marlin	3	0.87	0.57-1.33	63.65%	0.51	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015; Amorim *et al.*,2015
SAI – Atlantic sailfish	2	0.23	0.14-0.39	0%	**<0.0001**	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.*, 2015
WHM – White marlin	2	0.41	0.16-1.03	69.63%	0.06	Coelho *et al.*, 2012; Amorim *et al.*,2015

Table 6. Summary of the results of the meta-analysis on retention rates showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a higher retention was calculated on wire leader vs nylon leader. If the p-value <0.05 the RR is significantly different from 1 (in bold). I² describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	#exp	RR	CI	I²	p-value	References
Elasmobranchs						
BSH – Blue shark	5	1.44	1.27-1.64	44.70%	**<0.0001**	Vega *et al.*, 2009; Afonso *et al.*, 2012; Santos *et al.*, 2017; Santos & Coelho, 2016 44, 45, 51, 52
BTH – Bigeye thresher	2	0.37	0.06-2.25	64.20%	0.28	Santos *et al.*, 2017; Santos & Coelho, 2016
FAL – Silky shark	3	1.22	0.59-2.50	49.67%	0.59	Afonso *et al.*, 2012; Ward *et al.*, 2008; Santos & Coelho, 2016 45,48,52
OCS – Oceanic whitetip	2	0.99	0.19-5.56	82.27%	0.99	Afonso *et al.*, 2012; Santos & Coelho, 2016
PSK – Crocodile shark	2	0.62	0.39-1.00	0.0%	**0.05**	Afonso *et al.*, 2012; Santos & Coelho, 2016
SMA – Shortfin mako	2	2.23	0.67-7.45	84.91%	0.19	Vega *et al.*, 2009; Santos *et al.*, 2017
PLS – Pelagic stingray	4	0.32	0.08-1.30	88.59%	0.11	Vega *et al.*, 2009; Afonso *et al.*, 2012; Santos *et al.*, 2017; Santos & Coelho, 2016
Target species						
SWO – Swordfish	4	0.69	0.46-1.04	96.33%	0.08	Vega *et al.*, 2009; Afonso *et al.*, 2012; Santos *et al.*, 2017; Santos & Coelho, 2016
ALB – Albacore	2	0.36	0.14-0.90	0.0%	**0.03**	Afonso *et al.*, 2012; Santos *et al.*, 2017
BET – Bigeye tuna	3	0.75	0.32-1.76	90.53%	0.51	Afonso *et al.*, 2012; Santos *et al.*, 2017; Santos & Coelho, 2016
YFT – Yellowfin tuna	4	0.23	0.06-0.93	86.47%	**0.04**	Vega *et al.*, 2009; Afonso *et al.*, 2012; Santos *et al.*, 2017; Santos & Coelho, 2016
BUM – Atlantic blue marlin	3	0.63	0.41-0.97	0.0%	**0.04**	Afonso *et al.*, 2012; Santos *et al.*, 2017; Santos & Coelho, 2016
SAI – Atlantic sailfish	3	1.13	0.73-1.74	0.0%	0.58	Afonso *et al.*, 2012; Santos & Coelho, 2016

Table 7. Summary of the results of the meta-analysis on mortality showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a shark mortality was calculated on circle hooks vs J-hooks. If the p-value <0.05 the RR is significantly different from 1 (in bold). I^2 describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	**#exp**	**RR**	**CI**	**I^2**	**p-value**	**References**
Elasmobranchs						
BSH – Blue shark	8	0.82	0.71 - 0.96	92.15	**0.01**	Afonso *et al.*, 2011; NMFS, 2011; Pacheco *et al.*, 2011; Epperly *et al.* 2012; Coelho *et al.*, 2012; Afonso *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
BTH – Bigeye thresher	4	1.17	1.07 - 1.28	0.02	**<0.001**	NMFS, 2011; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
FAL – Silky shark	7	0.75	0.7 - 0.81	4.58	**<0.001**	Afonso *et al.*, 2011; NMFS, 2011; Pacheco *et al.*, 2011; Coelho *et al.*, 2012; Afonso *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
LMA – Longfin mako	3	1.2	0.7 - 2.08	0.0	0.51	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
OCS – Oceanic whitetip	6	0.73	0.57 - 0.95	0.0	**0.02**	Afonso *et al.*, 2011; Pacheco *et al.*, 2011; Coelho *et al.*, 2012; Afonso *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
POR – Porbeagle	3	0.89	0.79 - 1.01	3.32	0.06	NMFS, 2011; Epperly *et al.* 2012; Amorim *et al.*, 2015
PSK – Crocodile shark	4	1.23	0.85 - 1.78	0.0	0.27	Pacheco *et al.*, 2011; Afonso *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
SMA – Shortfin mako	7	0.9	0.83 - 0.97	0.01	**<0.001**	Afonso *et al.*, 2011; NMFS, 2011; Pacheco *et al.*, 2011; Epperly *et al.* 2012; Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
SPL – Scalloped hammerhead	4	0.79	0.73 - 0.86	0.0	**<0.001**	Afonso *et al.*, 2011; NMFS, 2011; Pacheco *et al.*, 2011; Coelho *et al.*, 2012
SPZ – Smooth hammerhead	2	1.04	0.92 - 1.18	0.0	0.54	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015
TIG – Tiger shark	5	1.39	0.92 - 2.1	0.0	0.12	Afonso *et al.*, 2011; NMFS, 2011; Coelho *et al.*, 2012; Afonso *et al.*, 2012; Fernandez-Carvalho *et al.* 2015

Table 8. Summary of the results of the meta-analysis on mortality showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a higher mortality was calculated on fish baited hooks vs squid baited hooks. If the p-value <0.05 the RR is significantly different from 1 (in bold). I^2 describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	**#exp**	**RR**	**CI**	**I^2**	**p-value**	**References**
Elasmobranchs						
BSH – Blue shark	4	1.71	1.50 – 1.95	69.59	**<0.001**	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015; Santos & Coelho, 2016
BTH – Bigeye thresher	4	1.06	0.91 – 1.2	31.63	0.43	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015; Santos & Coelho,2016
FAL – Silky shark	4	0.91	0.57 – 1.45	70.31	0.7	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015; Santos & Coelho, 2016
LMA – Longfin mako	2	0.76	0.33 – 1.72	35.34	0.51	Coelho *et al.*, 2012; Amorim *et al.*, 2015
OCS – Oceanic whitetip	4	1.24	0.95 – 1.63	0.0	0.12	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015; Santos & Coelho, 2016
PSK – Crocodile shark	3	0.9	0.58 – 1.42	14.21	0.66	Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015; Santos & Coelho, 2016
SMA – Shortfin mako	4	1.11	0.95 – 1.30	0.0	0.18	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015; Santos & Coelho, 2016
SPZ – Smooth hammerhead	4	0.93	0.82 – 1.05	6.41	0.25	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015; Santos & Coelho, 2016

Table 9. Summary of the results of the meta-analysis on mortality showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a higher mortality was calculated on fish baited J-hooks vs squid baited J-hooks. If the p-value <0.05 the RR is significantly different from 1 (in bold). I² describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	**#exp**	**RR**	**CI**	**I²**	**p-value**	**References**
Elasmobranchs						
BSH – Blue shark	3	1.61	1.16 – 2.25	85.32	**<0.01**	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
BTH – Bigeye thresher	3	0.95	0.67 – 1.33	48.29	0.75	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
LMA – Longfin mako	2	0.99	0.27 – 3.64	0.0	0.99	Coelho *et al.*, 2012; Amorim *et al.*, 2015
OCS – Oceanic whitetip	2	1.04	0.53 – 2.02	32.02	0.91	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015
PSK – Crocodile shark	2	0.53	0.05 – 5.66	68.58	0.6	Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
SMA – Shortfin mako	3	1.20	0.68 – 2.10	66.86	0.54	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
SPZ – Smooth hammerhead	2	0.88	0.55 – 1.38	78.21	0.57	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015

Table 10. Summary of the results of the meta-analysis on mortality showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a higher mortality was calculated on squid baited circle hooks vs squid baited J-hooks. If the p-value <0.05 the RR is significantly different from 1 (in bold). I² describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	**#exp**	**RR**	**CI**	**I²**	**p-value**	**References**
Elasmobranchs						
BSH – Blue shark	3	0.67	0.49 – 0.94	81.92	**0.02**	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
BTH – Bigeye thresher	3	1.01	0.85 – 1.20	0.0	0.92	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
LMA – Longfin mako	2	1.58	0.51 – 4.85	0.0	0.43	Coelho *et al.*, 2012; Amorim *et al.*, 2015
OCS – Oceanic whitetip	2	0.75	0.3 – 1.88	62.99	0.54	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015
PSK – Crocodile shark	2	0.99	0.49 – 2.01	0.0	0.98	Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
SMA – Shortfin mako	3	0.99	0.55 – 1.77	73.22	0.96	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
SPZ – Smooth hammerhead	2	0.93	0.77 – 1.13	25.43	0.47	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015

Table 11. Summary of the results of the meta-analysis on mortality showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a higher mortality was calculated on fish baited circle hooks vs squid baited J-hooks. If the p-value <0.05 the RR is significantly different from 1 (in bold). I² describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	#exp	RR	CI	I²	p-value	References
Elasmobranchs						
BSH – Blue shark	3	1.26	1.05 – 1.51	56.98	**0.01**	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
BTH – Bigeye thresher	3	1.19	0.94 – 1.50	32.62	0.15	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
LMA – Longfin mako	2	1.20	0.36 – 3.99	0.0	0.77	Coelho *et al.*, 2012; Amorim *et al.*, 2015
OCS – Oceanic whitetip	2	0.98	0.59 -1.63	18.49	0.94	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015
PSK – Crocodile shark	2	1.08	0.48 – 2.40	13.04	0.86	Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
SMA – Shortfin mako	3	1.06	0.81 – 1.37	0.0	0.68	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015; Amorim *et al.*, 2015
SPZ – Smooth hammerhead	2	0.91	0.76 – 1.09	23.88	0.29	Coelho *et al.*, 2012; Fernandez-Carvalho *et al.* 2015

Table 12. Summary of the results of the meta-analysis on at-haulback mortality showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a higher at-haulback mortality was calculated on wire vs nylon leader. If the p-value <0.05 the RR is significantly different from 1 (in bold). I² describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	#exp	RR	CI	I²	p-value	References
Elasmobranchs						
BSH – Blue shark	3	0.88	0.76 – 1.00	0.0	0.06	Afonso *et al.*, 2012; Santos *et al.*, 2017; Santos & Coelho, 2016
BTH – Bigeye thresher	2	0.94	0.46 – 1.92	0.0	0.87	Santos *et al.*, 2017; Santos & Coelho, 2016
FAL – Silky shark	2	0.86	0.45 – 1.63	75.62	0.65	Afonso *et al.*, 2012; Santos & Coelho, 2016
PSK – Crocodile shark	3	1.47	0.78 – 2.75	35.52	0.23	Afonso *et al.*, 2012; Santos *et al.*, 2017; Santos & Coelho, 2016

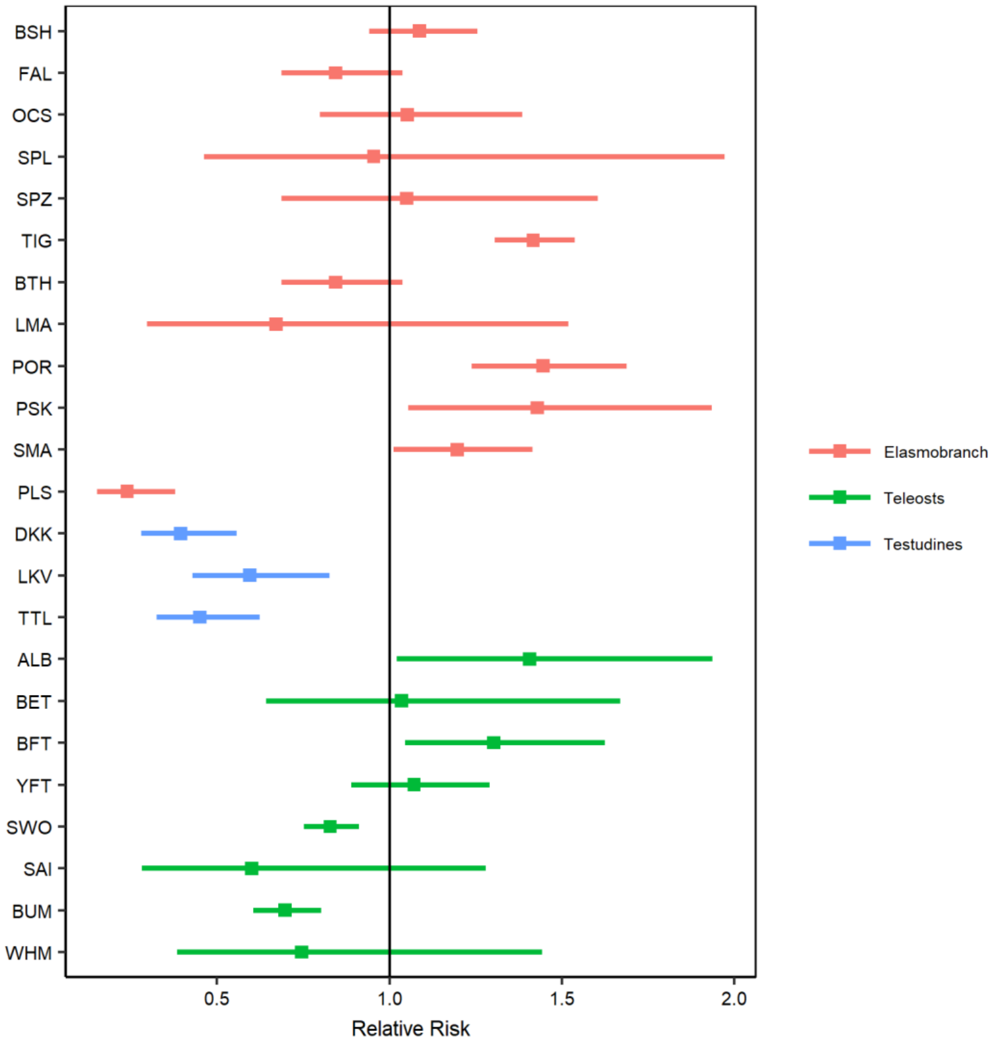

Figure 1. Effect size (relative risk—RR) of hook type (circle or J-hook) on retention rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher retention was calculated on circle hooks vs J-hooks.

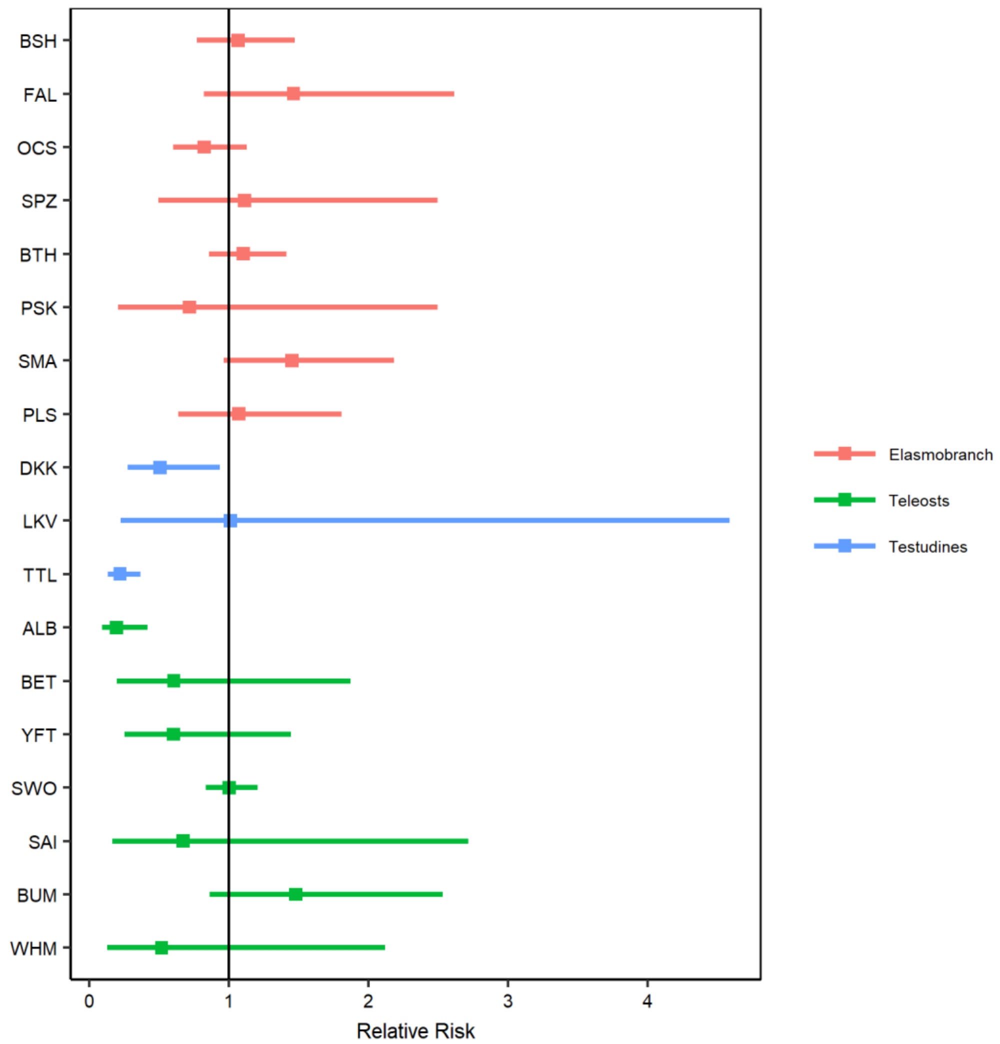

Figure 2. Effect size (relative risk—RR) of hook type (squid or fish) on retention rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher retention was calculated on fish baited hooks vs squid baited hooks.

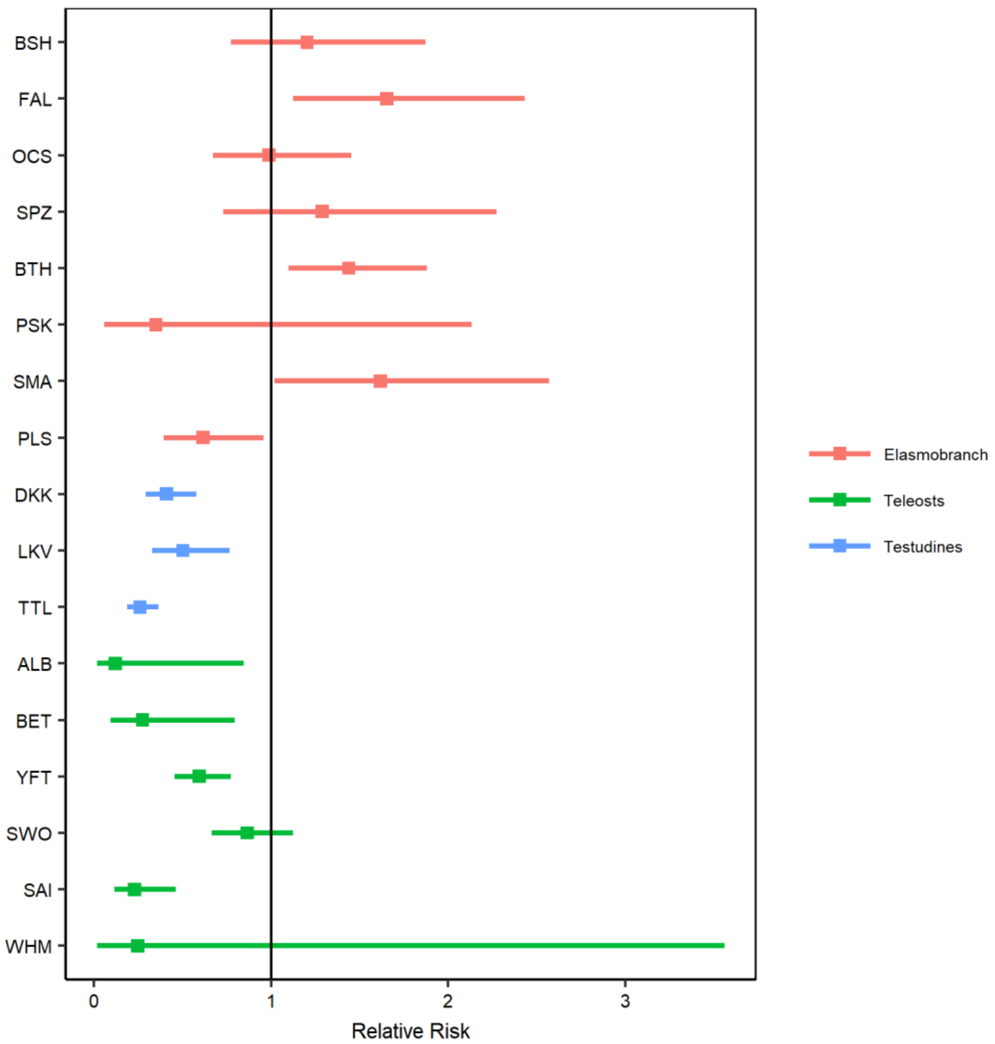

Figure 3. Effect size (relative risk—RR) of fish baited J-hooks compared with squid baited J-hooks on retention rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher retention was calculated on fish baited J-hooks vs squid baited J-hooks.

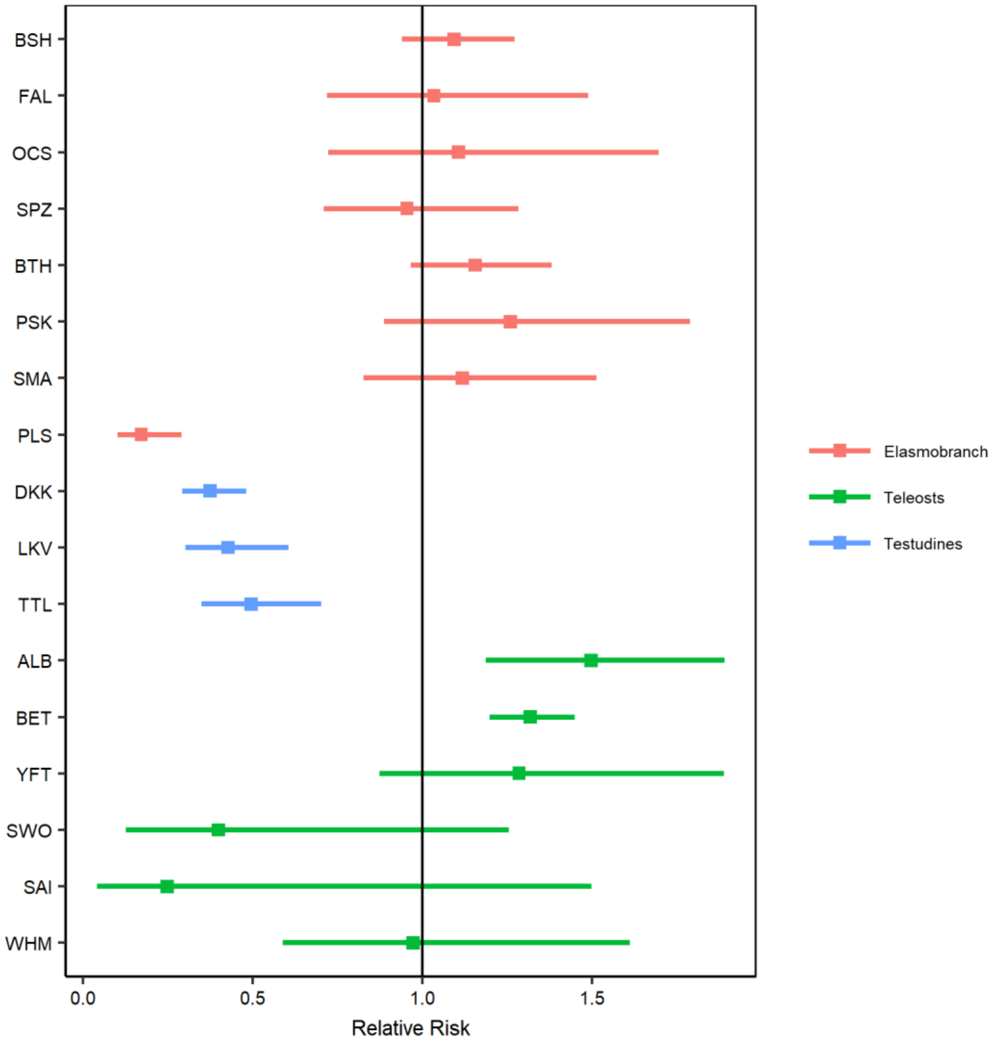

Figure 4. Effect size (relative risk—RR) of squid baited circle hooks compared with squid baited J-hooks on retention rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher retention was calculated on squid baited circle hooks vs squid baited J-hooks.

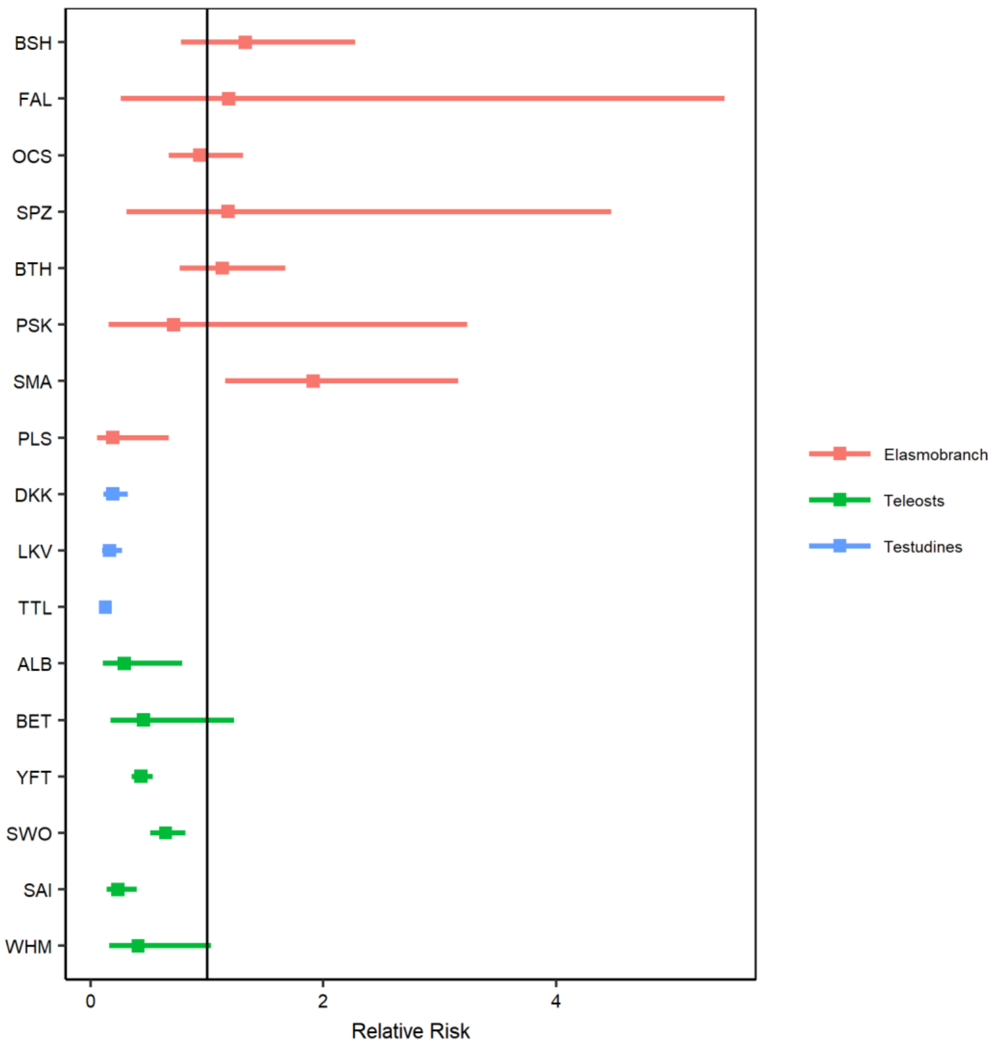

Figure 5. Effect size (relative risk—RR) of fish baited circle hooks compared with squid baited J-hooks on retention rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher retention was calculated on fish baited circle hooks vs squid baited J-hooks.

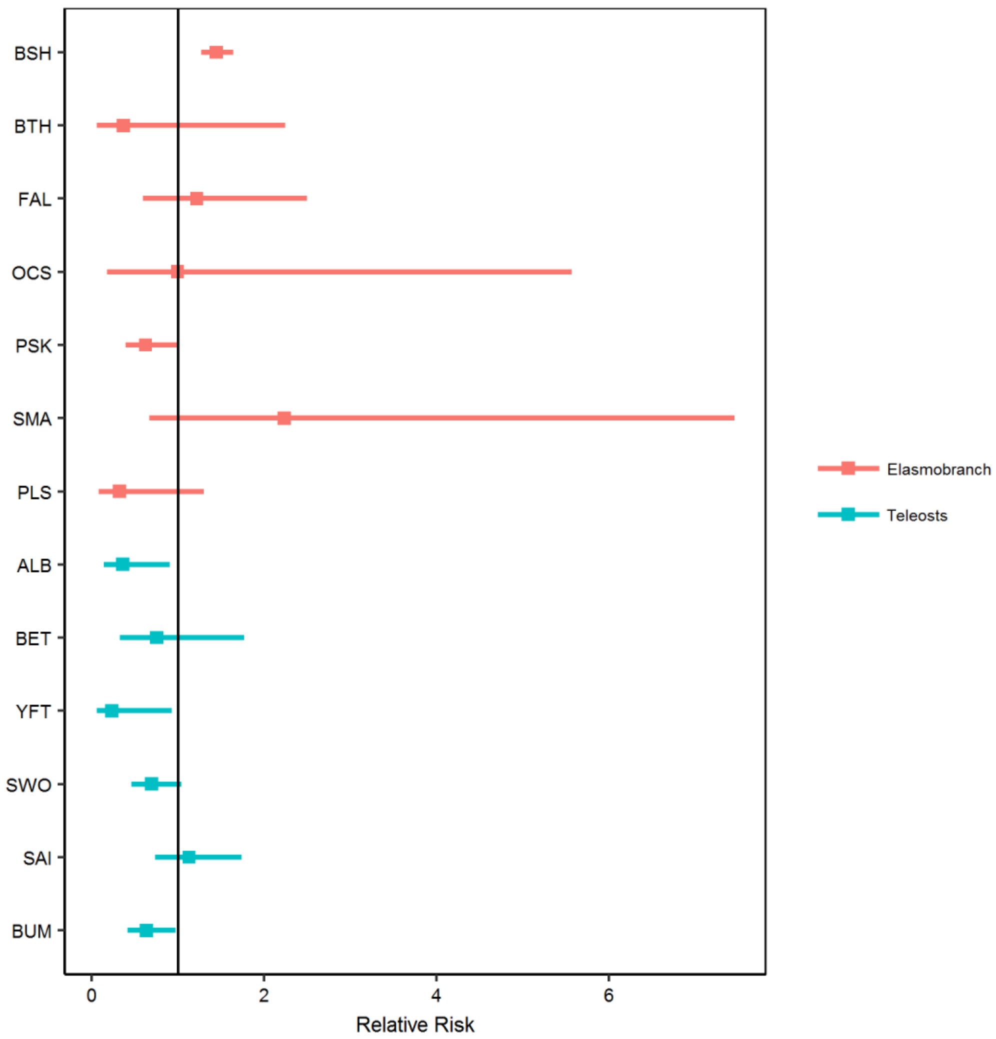

Figure 6. Effect size (relative risk—RR) of wire leaders compared with nylon leaders on retention rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher retention was calculated on wire leader vs nylon leader.

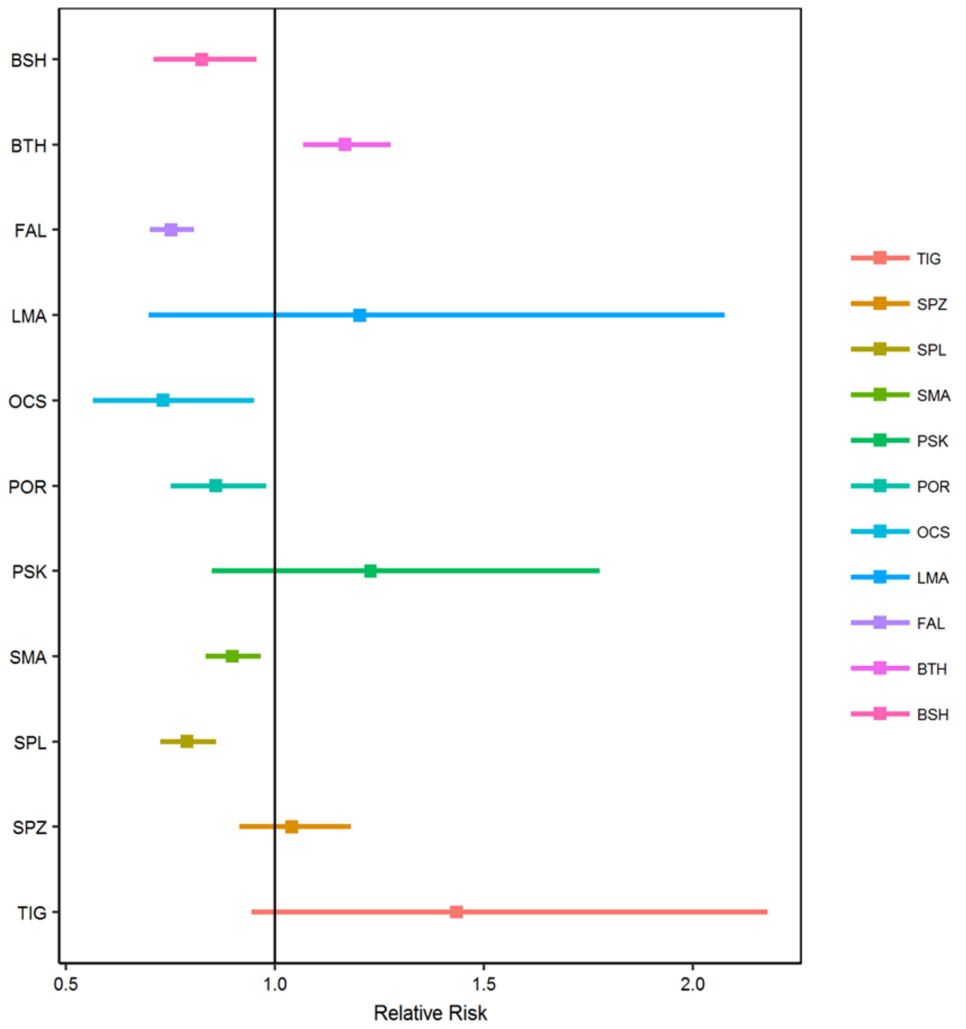

Figure 7. Effect size (relative risk—RR) of hook type (circle or J-hook) on at-haulback mortality rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher mortality was calculated on circle hooks vs J-hooks.

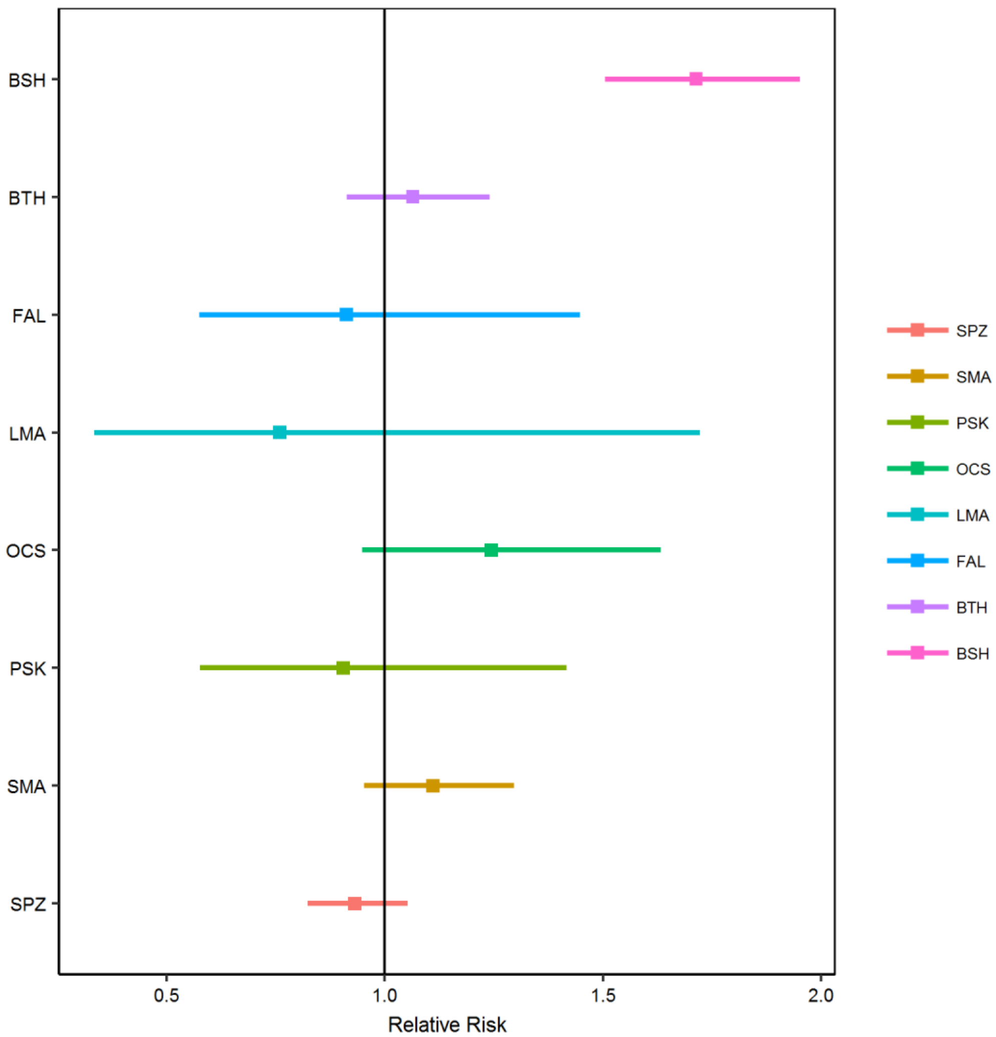

Figure 8. Effect size (relative risk—RR) of bait type (squid or fish) on at-haulback mortality rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher mortality was calculated on fish baited hooks vs squid baited hooks.

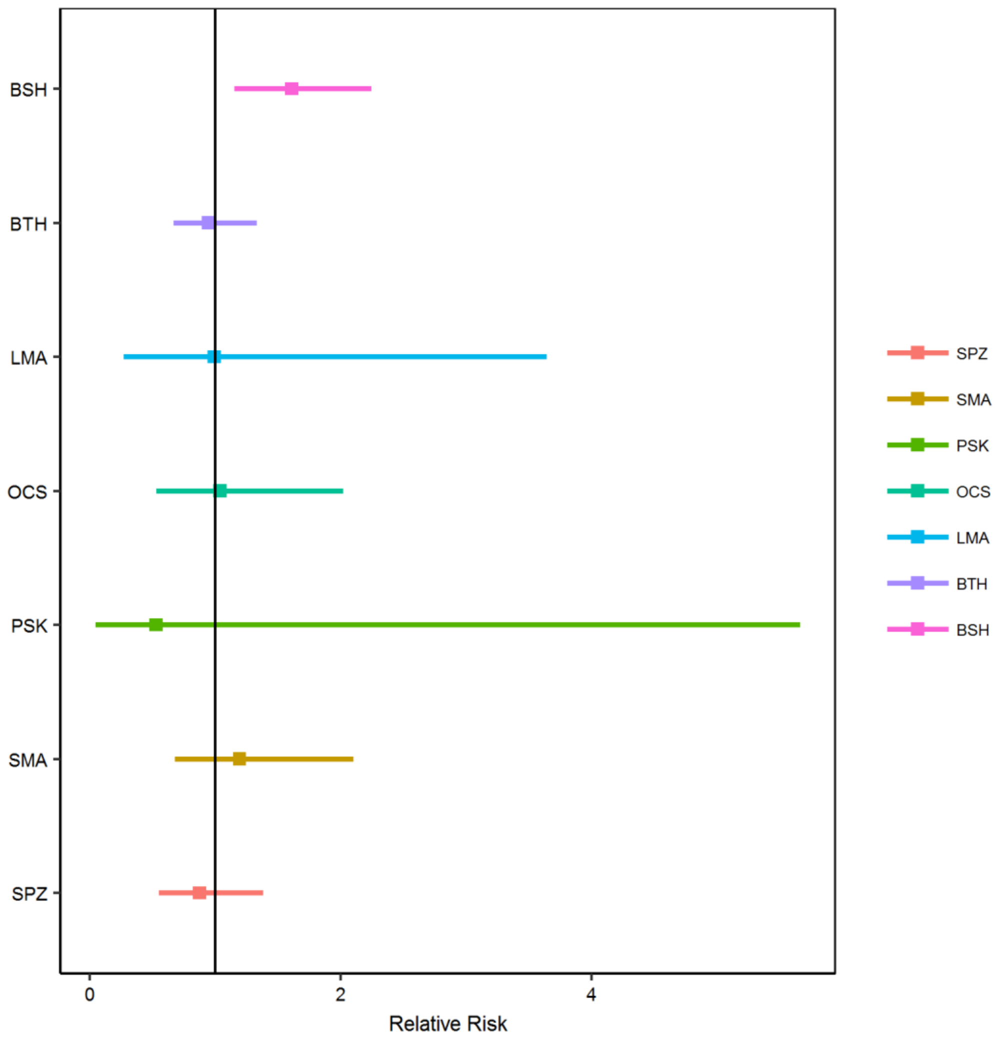

Figure 9. Effect size (relative risk—RR) of fish baited J-hooks compared with squid baited J-hooks on at-haulback mortality rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher mortality was calculated on fish baited J-hooks vs squid baited J-hooks.

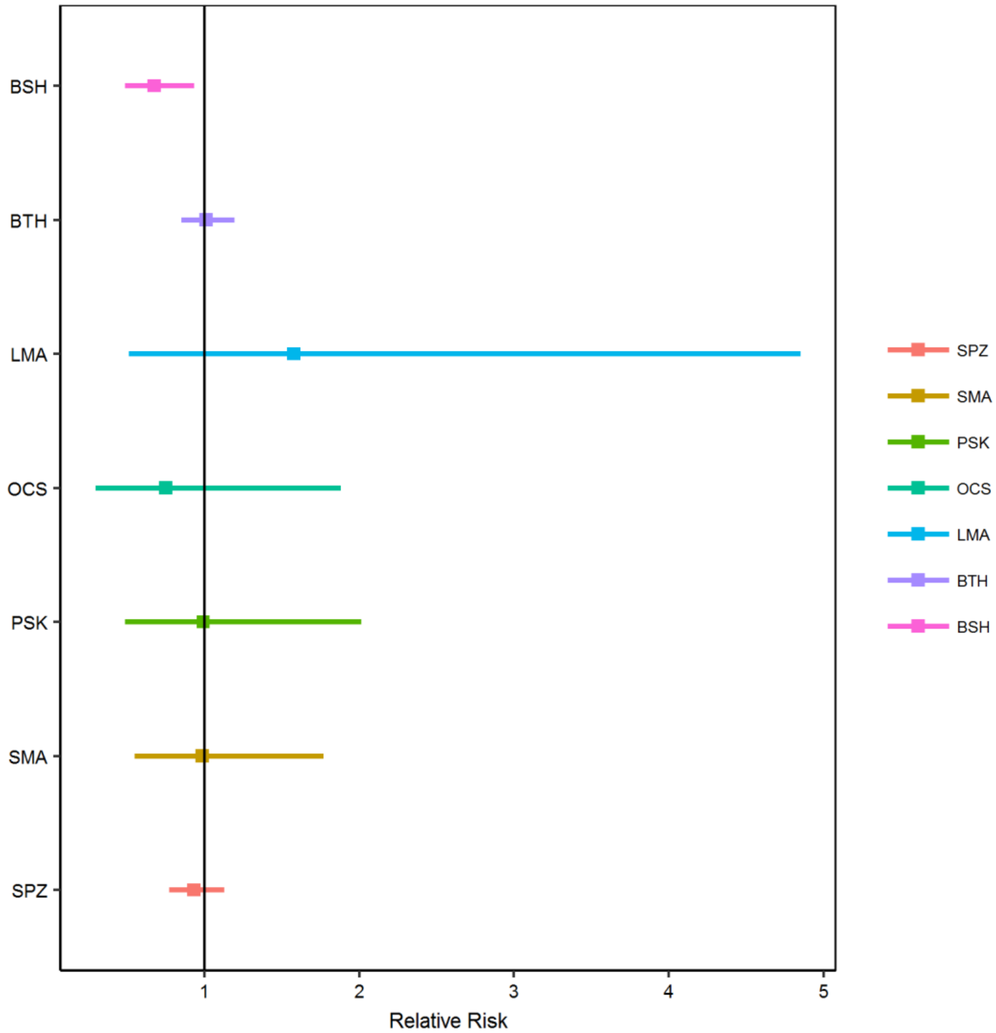

Figure 10. Effect size (relative risk—RR) of squid baited circle hooks compared with squid baited J-hooks on at-haulback mortality rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher mortality was calculated on squid baited circle hooks vs squid baited J-hooks.

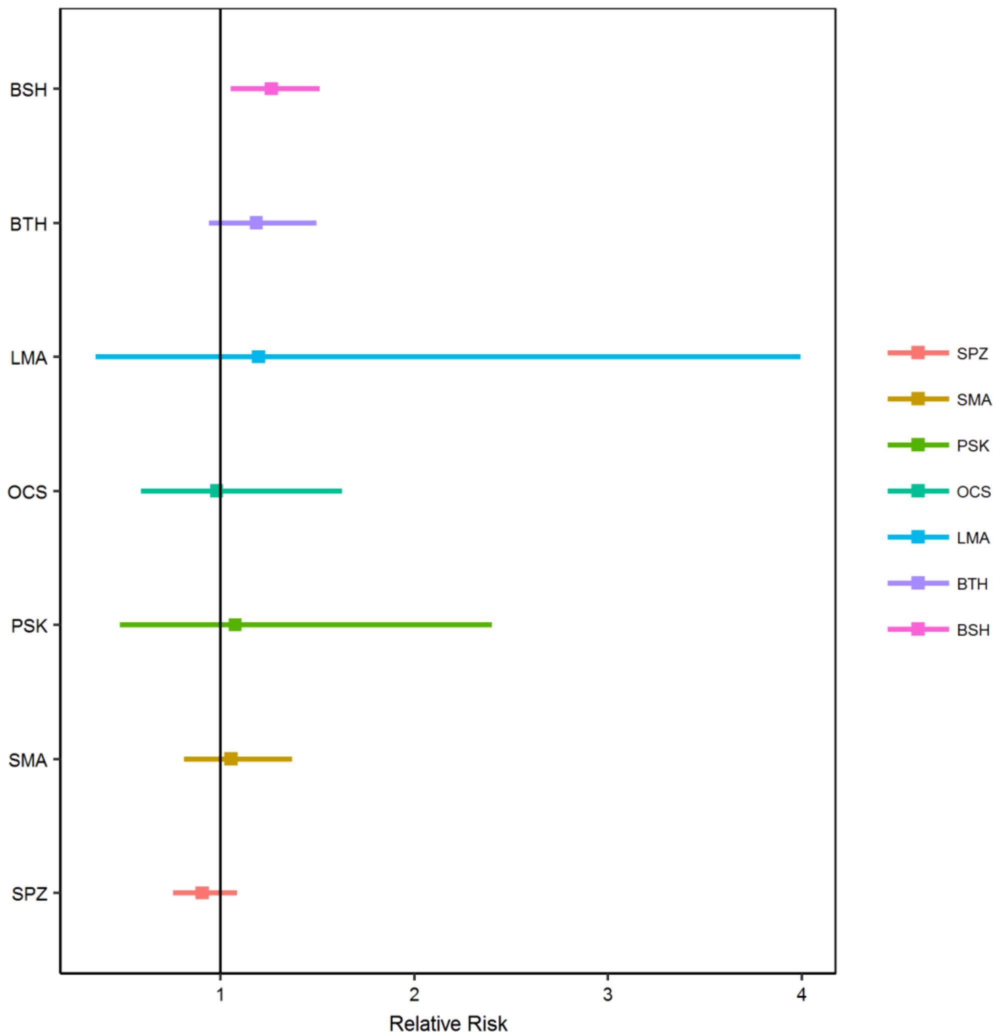

Figure 11. Effect size (relative risk—RR) of fish baited circle hooks compared with squid baited J-hooks on at-haulback mortality rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher mortality was calculated on fish baited circle hooks vs squid baited J-hooks.

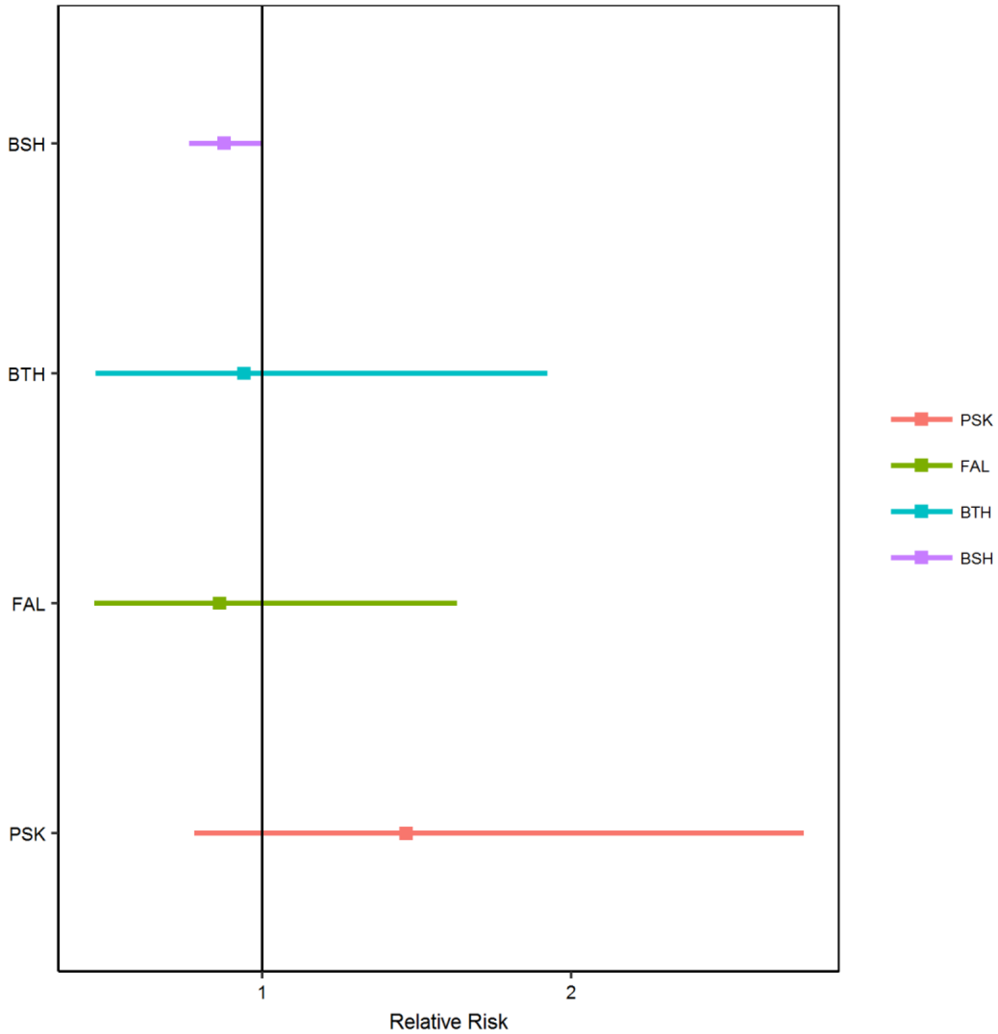

Figure 12. Effect size (relative risk—RR) of wire leaders compared with nylon leaders on at-haulback mortality rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher mortality was calculated on wire leader vs nylon leader.